Retrievals of SO2 and HNO3

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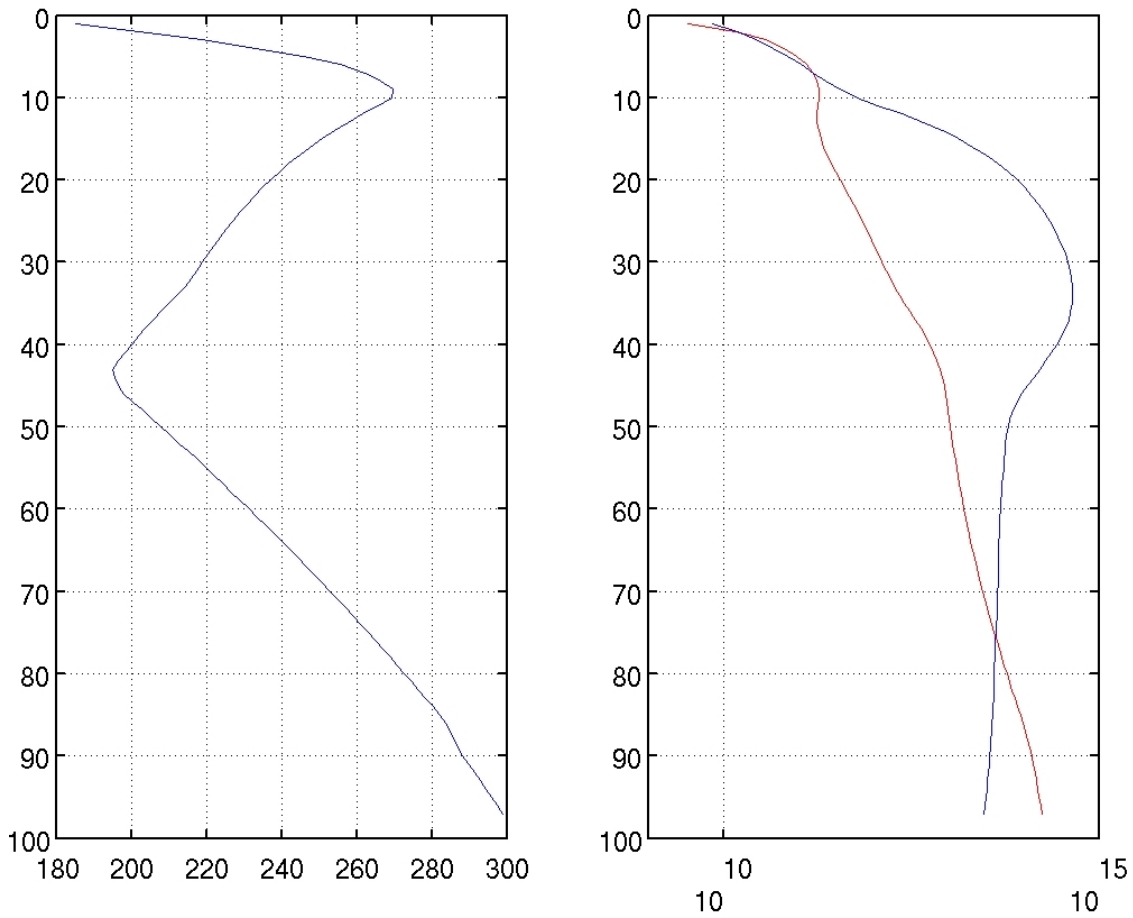
Introduction

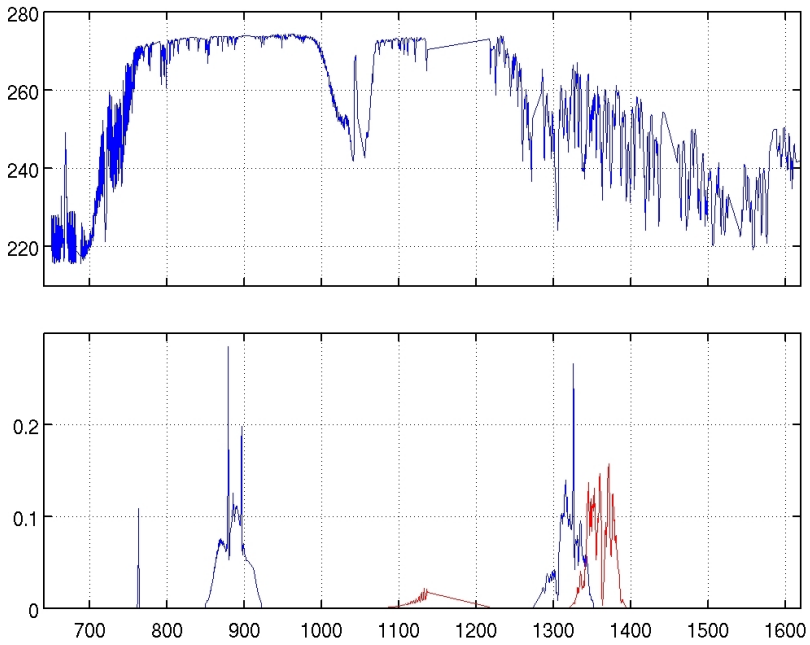
- AIRS has some sensitivity to variable trace gases SO2 (sulfur dioxide) and HNO3 (nitric acid).
- These gases CAN be varied with the AIRS-RTA, but...
- ...these gases will NOT be retrieved in “version 5” processing.
- Using a relatively simple retrieval technique, I will demonstrate it is possible to retrieve these gases with AIRS, although some problems remain.
- My retrieval technique is not necessarily the best way to go about retrieving these gases, but it establishes a minimum of what is possible with AIRS.

Typical tropical profile



- (left) Temperature versus layer number.
- (right) Sample SO2 and HNO3 integrated layer gas amounts.

AIRS Sensitivity to SO2 and HNO3



- (top) BT spectra; (bottom) delta BT for SO2 x10, HNO3 x1.5
- SO2 sensitivity is strongest in the 7 um water band, with only a weak sensitivity in the 9 um window region. Thus AIRS is unable to detect lower troposphere SO2 unless the profile is very dry and/or the SO2 very large.
- AIRS is equally sensitive to HNO3 in two spectral regions, one inside the 7 um water band, and the other in the 11 um window region.

SO2 considerations

- The global background level of SO2 is 0.1 Dobson Unit (DU).
- Max volcanic SO2 up to 1000 DU, but typically less than 100 DU.
- Few volcanos at high latitudes where air is typically dry.
- The NEdT of the 7 um SO2 channels is typically 0.1 K.
- Since the delta BT of a x10 increase in SO2 over the background level is similar in magnitude to the NEdT, then our lower limit on sensitivity to SO2 is roughly 1 DU.
- Significant volcanic events often spew SO2 plumes of 10 or more DU high into the upper troposphere (8-15 km). This places the SO2 above most clouds, and changes to the AIRS observed BT in the 7 um SO2 channels can be many Kelvin.
- Unless the profile is very dry, the water absorption in the 7 um SO2 channels blocks most of the upwelling radiance from the surface and lower troposphere.

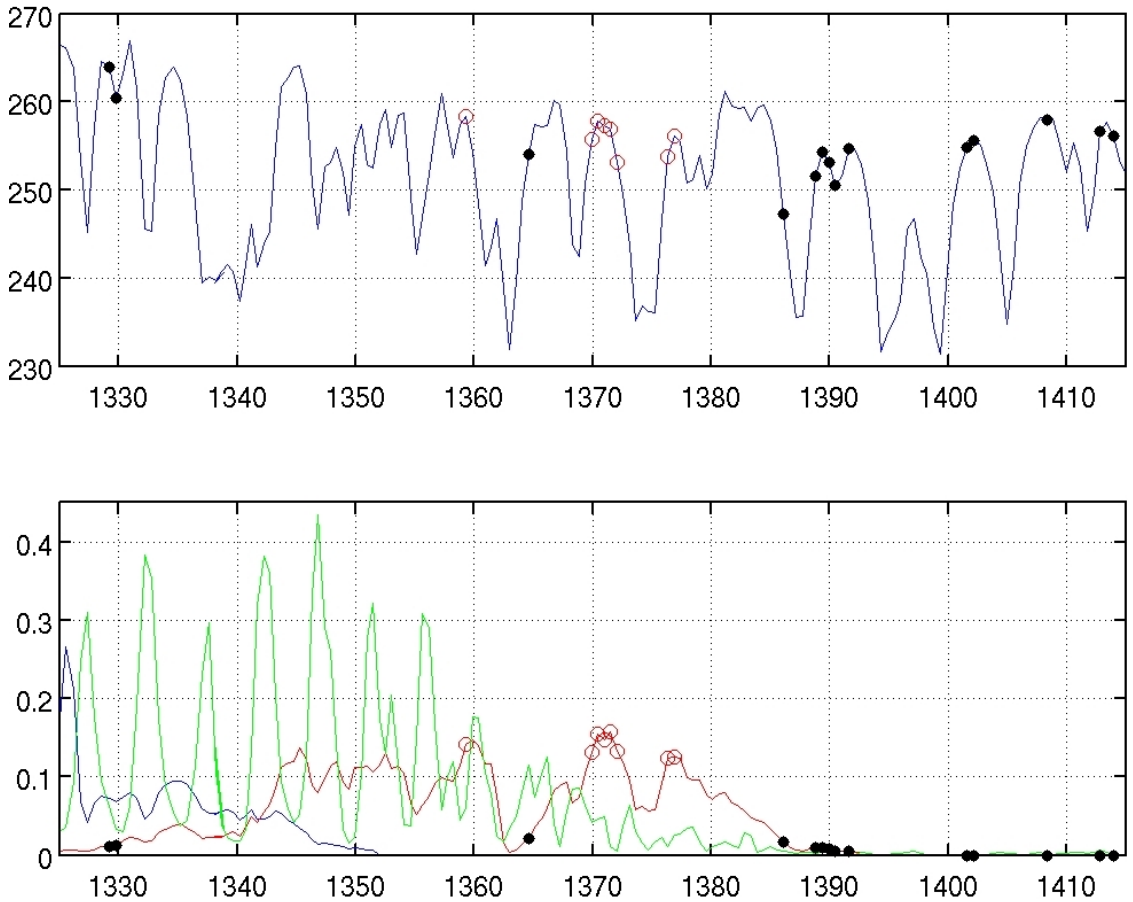
HNO3 considerations

- HNO3 varies with season and latitude, but roughly speaking the the global nominal HNO3 profile has a total column of 0.4 DU. Of this, about 0.3 DU is in the stratosphere.
- HNO3 tends to be largest at the poles and smallest in the tropics.
- Based on retrievals from the Microwave Limb Sounder (MLS) on Aura, stratospheric HNO3 variations are roughly x0.2 to x5 the nominal.
- The delta BT due to HNO3 variations is at most a few Kelvin.
- The 11 um channels NEdT is 0.3 K, and 0.15 K for 7 um channels.
- Since the delta BT for a x1.5 increase in HNO3 over the nominal profile is similar in magnitude to the NEdT of the 7 um channels, then our lower limit on sensitivity to HNO3 is roughly 0.2 DU.
- The 11 um channels have large radiance contributions from the surface and lower troposphere even if the profile is wet.
- The 7 um channels are much less sensitive to the surface, but for dry profiles the surface contribution is significant.

Retrieval Methodology

- We use simple linear regression that uses channels insensitive to SO_2 or HNO_3 to predict radiances for channels sensitive to these gases.
- We then modify the trace gas amount to mimize the difference between the predicted radiance and the observed radiance for the channels sensitive to the trace gases.
- My retrieval restricts the trace gas variability to an overall scale factor applied to some range of AIRS layers.
  SO2 : layers 55-66 (190-344 mb)
  HNO3 : layers 20-45 (8-110 mb)

SO2 channels

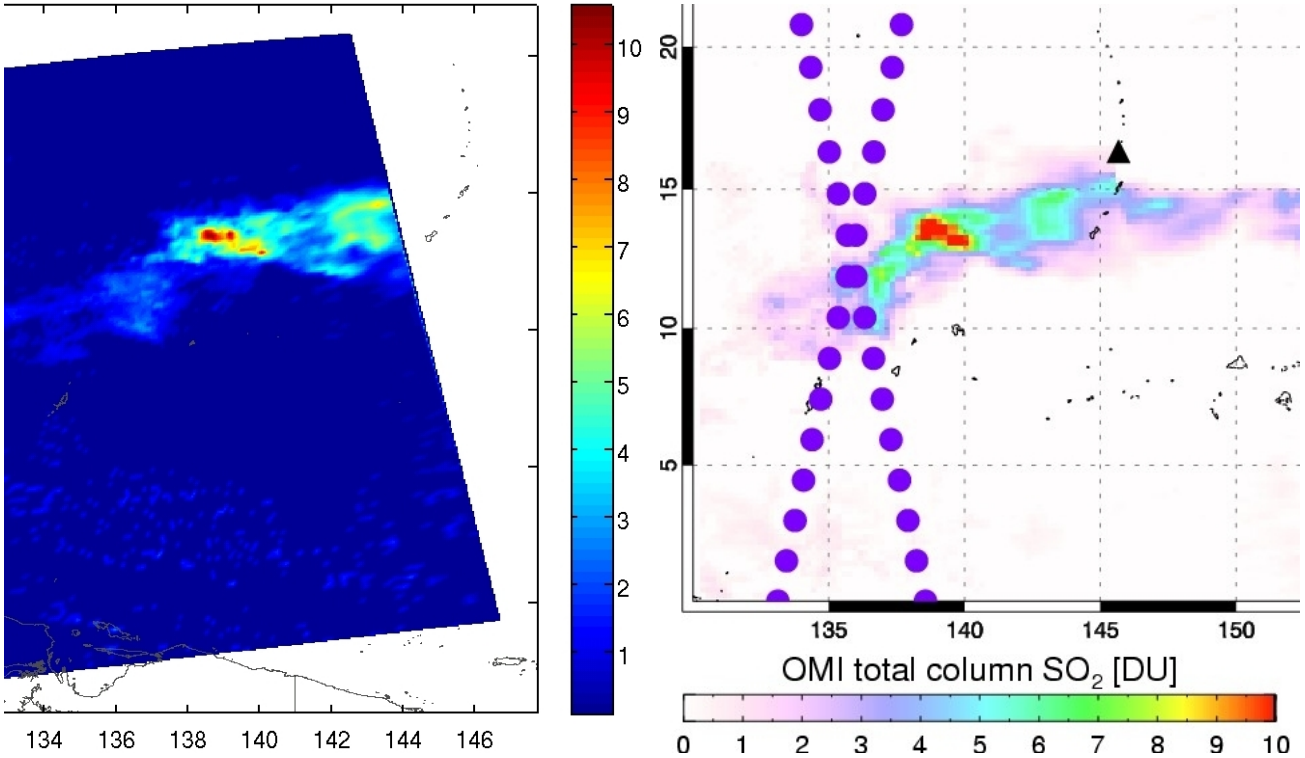


- (top) BT spectra; (bottom) delta BT for SO2 x10, HNO3 x1.5, CH4 x1.05
- o = “strong” SO2 channel, ▪ = “predictor” channel

SO2 retrieval overview

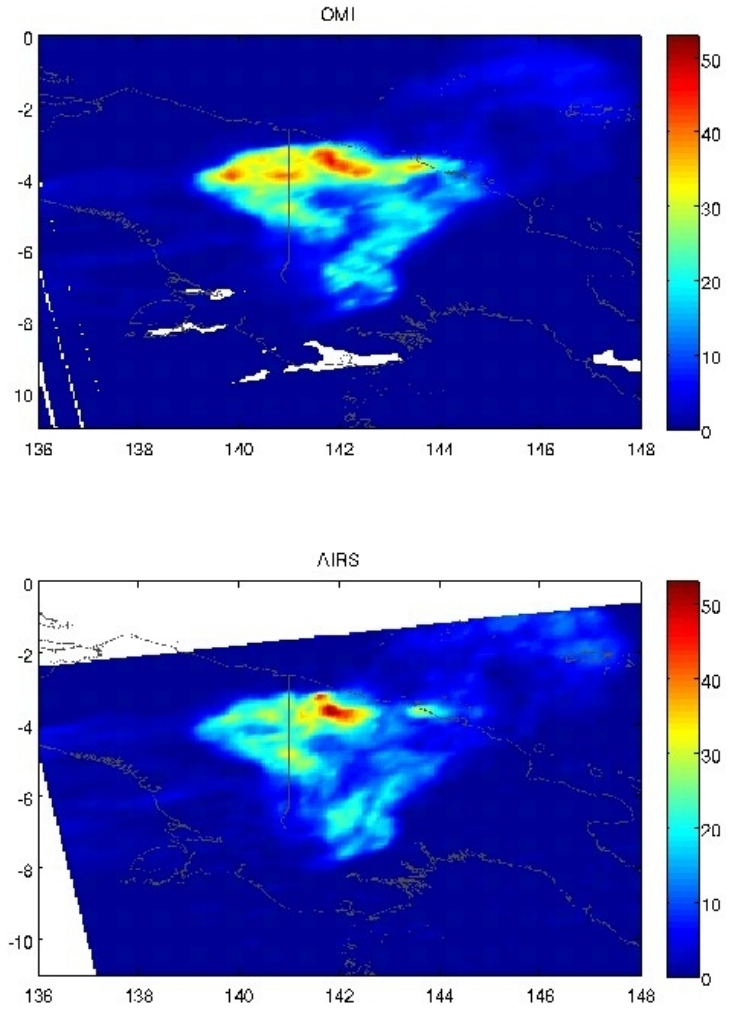
- Uses AIRS L1B radiance
- Uses ECMWF profile
- Retrieval on each individual AIRS observation
- No explicit adjustments for clouds
- SO2 variability is confined to a pre-set range of AIRS layers (55-66)
- Reported SO2 column spans top of atmosphere to surface

SO2 results, 2005/04/07 Mariana Islands

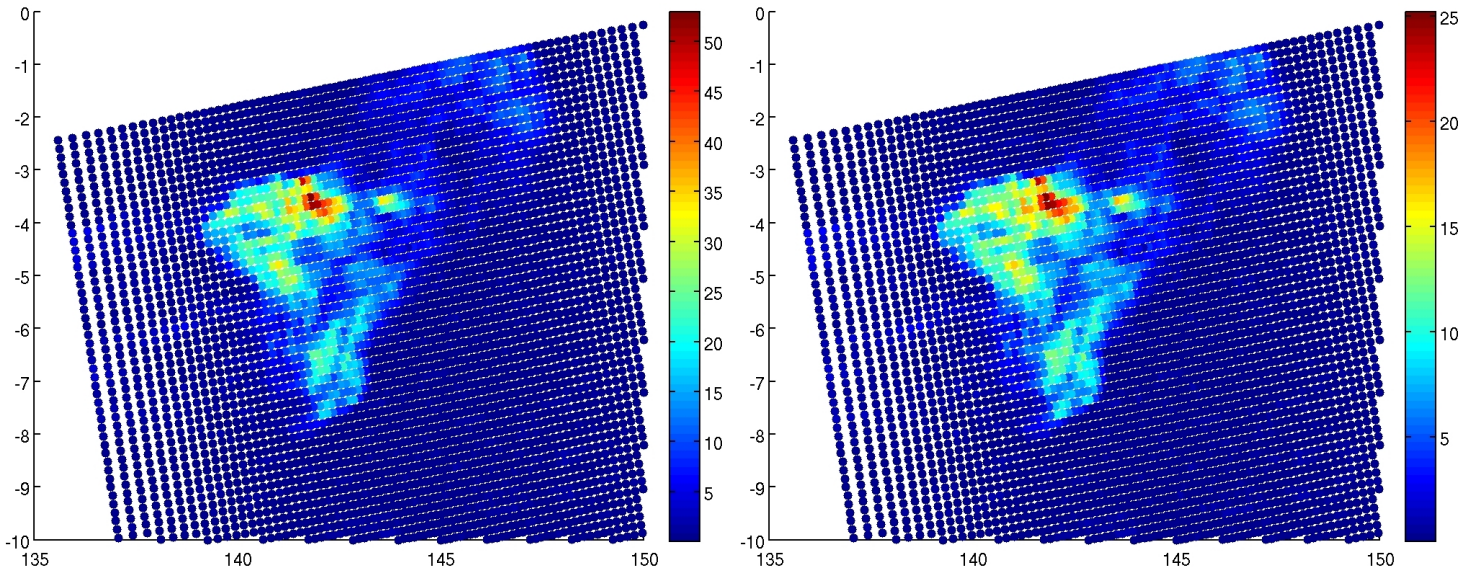


- (left) AIRS retrieval assuming the SO2 is in layers 55-66
- (right) OMI (on Aura) retrieval

SO2 results, 2005/01/28 New Guinea

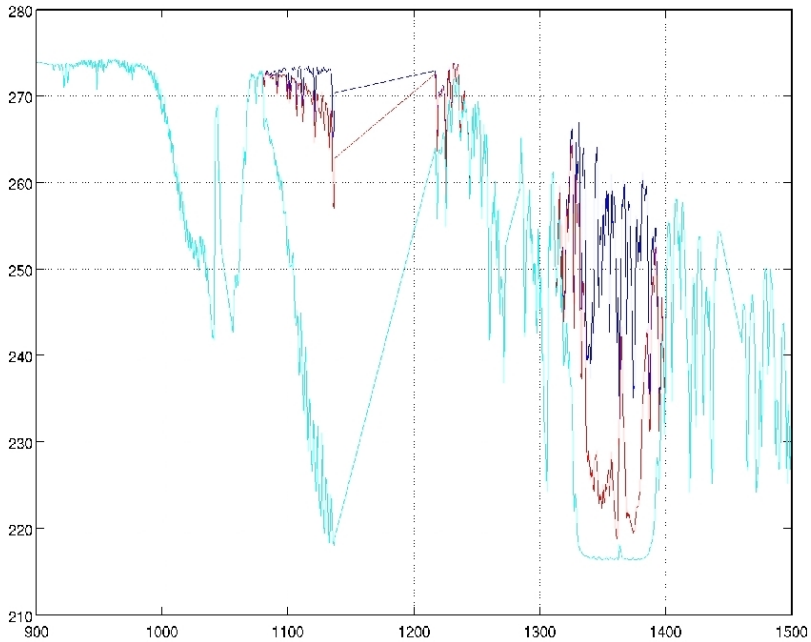


Alternate AIRS SO2 results, 2005/01/28 New Guinea



- (left) using layers 55-66 [190-344 mb]; (right) using layers 45-56 [103-212 mb]
- The two plots look almost identical, but notice the colorbar range changes by a factor of two!
- Can we determine where the SO2 is using AIRS? Unknown.

Limits of AIRS sensitivity to SO2



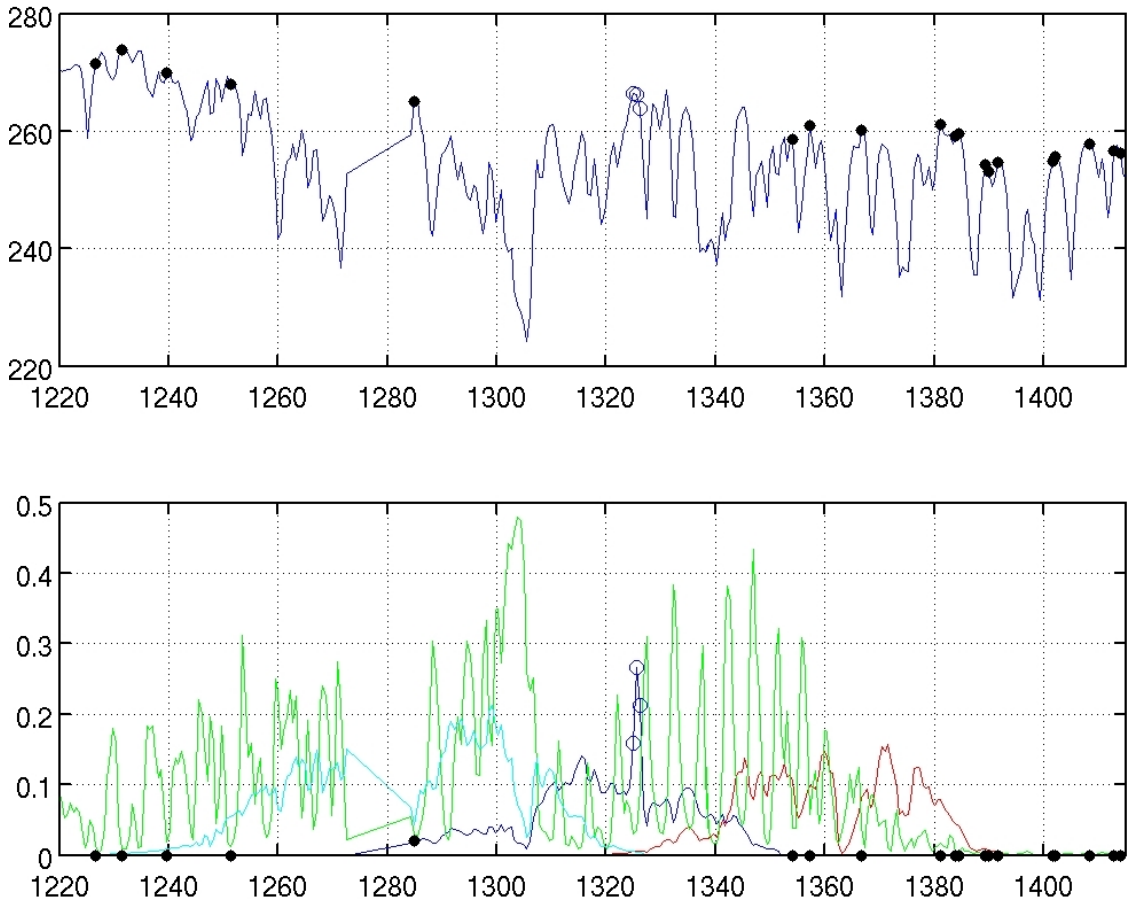
BT for SO2 column: 0.1 DU, 150 DU, 3700 DU.

- Rare extreme volcanic events can output up to 1000 DU.
- The 7 um channels lose sensitivy to SO2 above 150 DU...
- ...but the 11 um channels retain sensitivity to at least 3000 DU.
- My current SO2 retreival algorithm only uses the 7um channels, but it should be possible to supplement the code with a 11 um retrieval that allows for SO2 retrievals up to 3000 or more DU.

AIRS SO2 conclusions and comments

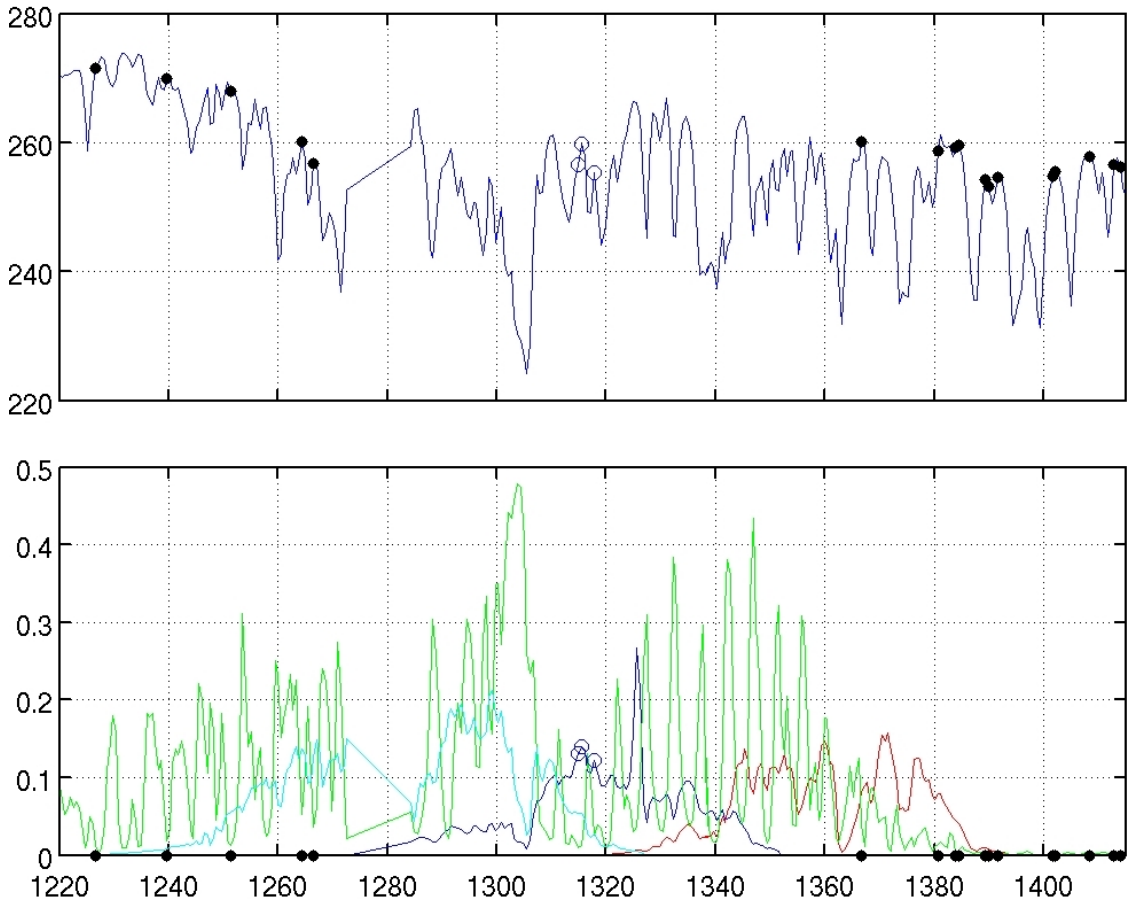
- A column retrieval of upper troposphere SO2 is possible if the amount is more than x10 above the nominal amount.
- Can retrieve upper trop SO2 on individual AIRS FOVs (rather 3x3), at least for wet profiles.
- All my SO2 retrievals have been at tropical latitudes; results may degrade at high latitudes where the air is much drier.
- Suspect AIRS has little ability to determine the SO2's vertical distribution (ie profile shape).
- Doubt AIRS will be useful for monitoring typical industrial SO2 pollution in the lower troposphere.

HNO3 channels version1



- (top) BT spectra; (bottom) delta BT for SO2 x10, HNO3 x1.5, CH4 x1.05, N2O x1.03
- o = “strong” HNO3 channel, ▪ = “predictor” channel

HNO3 channels version2

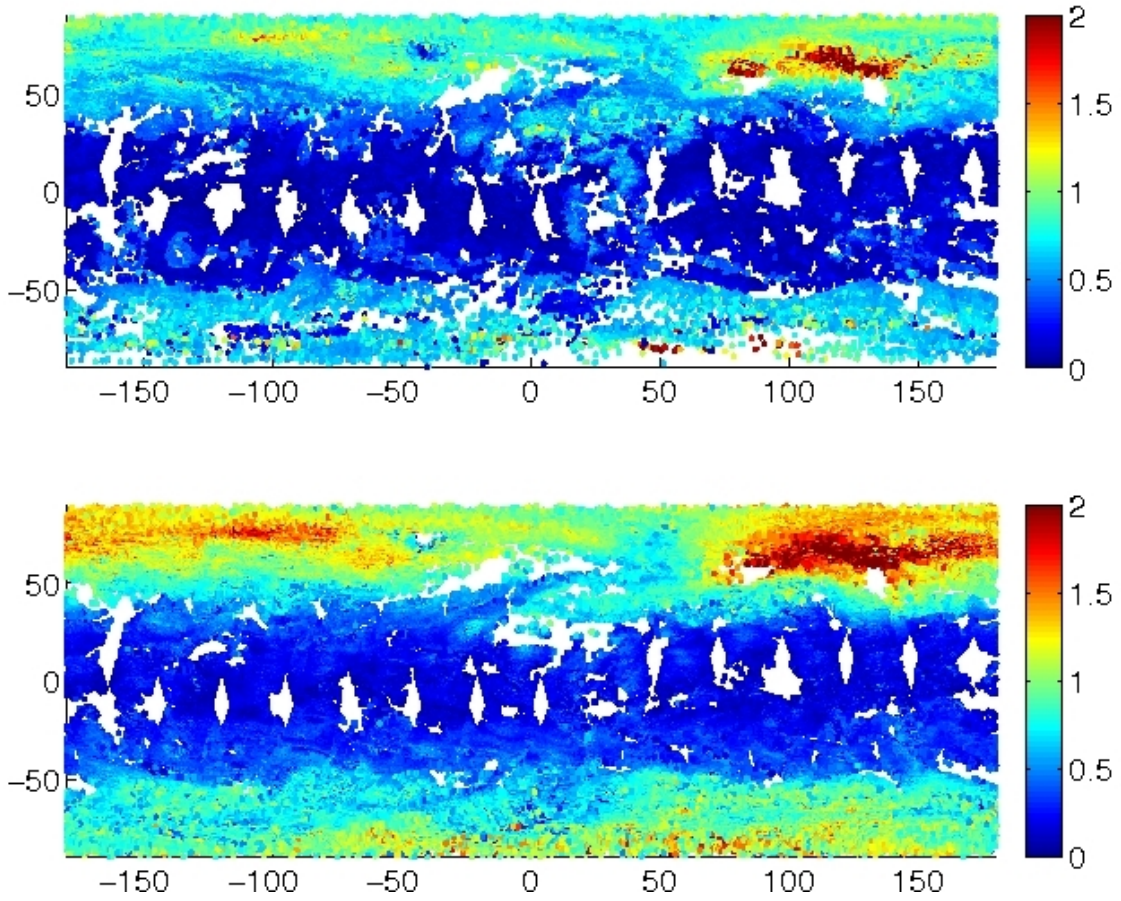


- (top) BT spectra; (bottom) delta BT for SO2 x10, HNO3 x1.5, CH4 x1.05, N2O x1.03
- o = "strong" HNO3 channel, ▪ = "predictor" channel

HNO3 retrieval overview

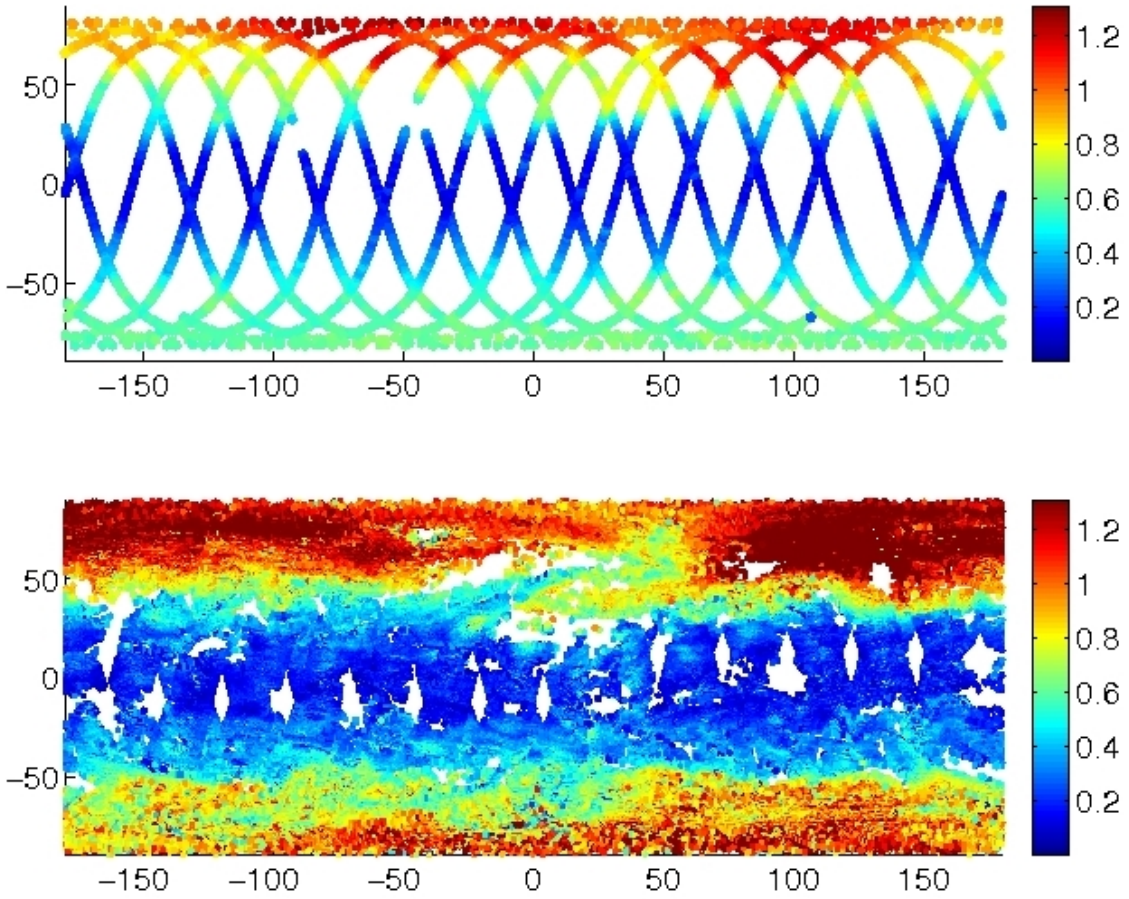
- Uses AIRS L2 Cloud-Cleared radiance (v4.6.2)
- Uses AIRS L2 Support Profile (v4.6.2)
- Retrieval on AMSU/AIRS 3x3 field of regard
- Ignores most L2 QA flags (otherwise little polar coverage)
- HNO3 variability is confined to a pre-set range of AIRS layers (20-45)
- Reported HNO3 column spans top of atmosphere to layer 50 (150 mb)

HNO3 results, AIRS version1 vs version2



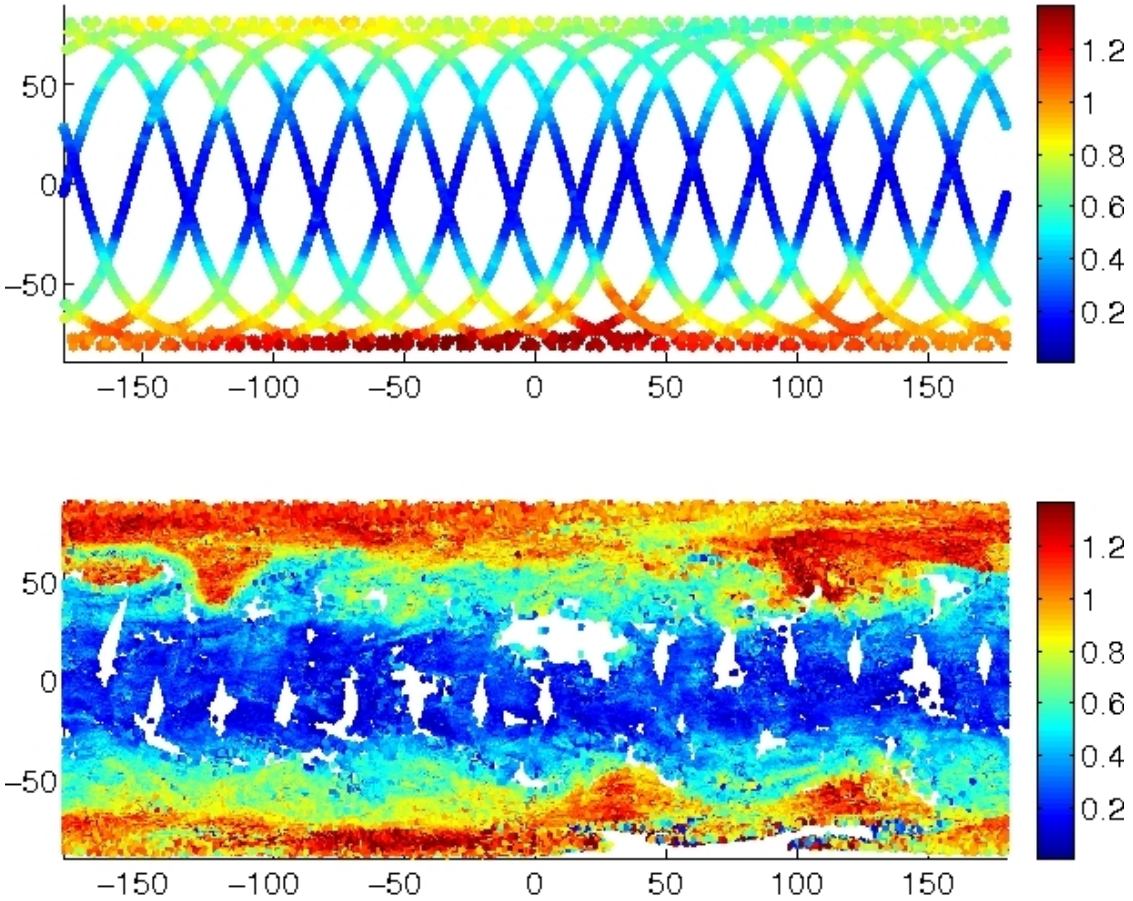
(top) AIRS HNO3 retrieval version1; (bottom) version2

HNO3 results, 2006/01/11



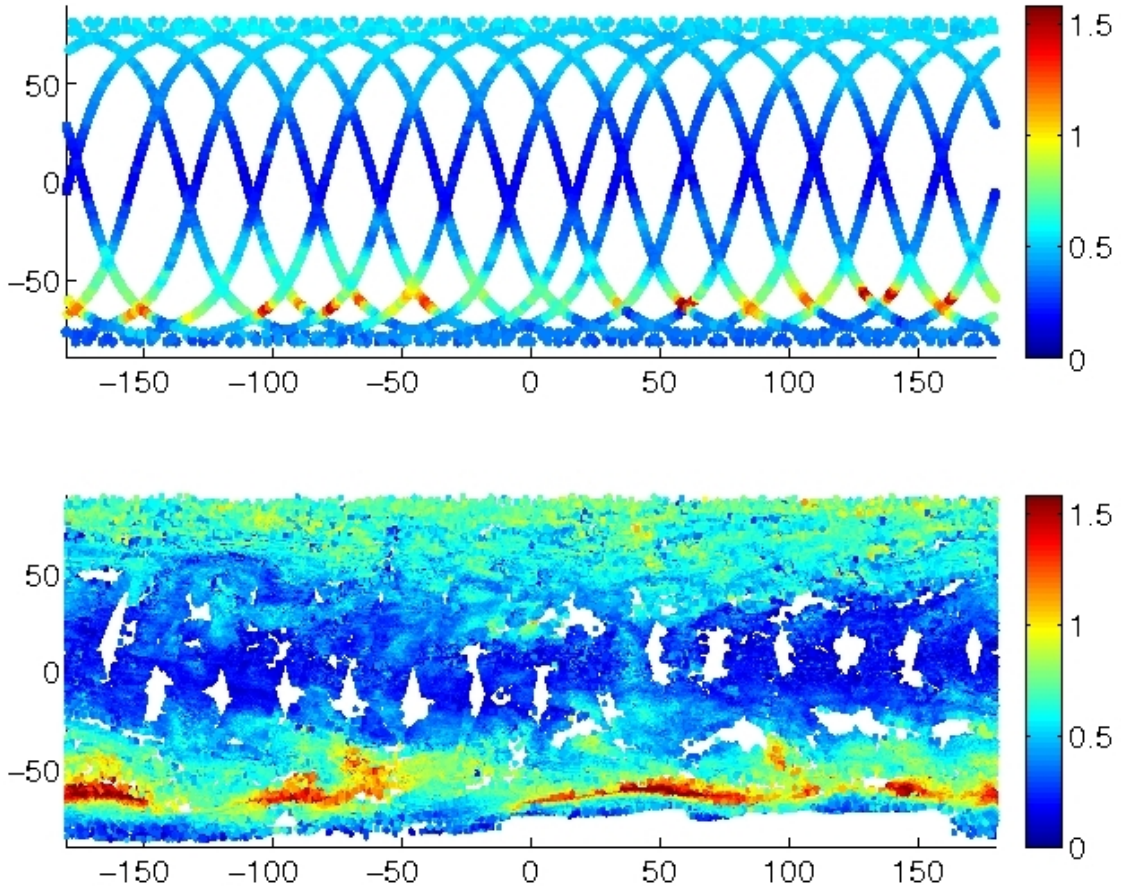
(top) MLS; (bottom) AIRS version2

HNO3 results, 2006/04/17



(top) MLS; (bottom) AIRS version2

HNO3 results, 2006/07/22



(top) MLS; (bottom) AIRS version2

AIRS HNO3 conclusions and comments

- HNO3 retrieval more difficult than for SO2, but ...
- ...retrieval of stratospheric SO2 is probably possible.
- HNO3 retrieval dependent on a good T and H2O profile down to at least the mid troposphere, and down to the surface if the air is dry (and it usually is at high latitudes where most HNO3 variabilty occurs).
- Suspect AIRS has little ability to determine the HNO3's vertical distribution (ie profile shape).
- Unlike MLS, AIRS could in theory detect lower tropospheric HNO3, but I do not know if tropospheric HNO3 varies enough for AIRS to notice.